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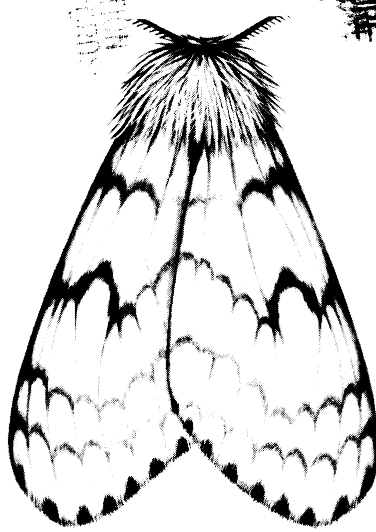
Gypsy Moth Egg-Mass Sampling With Fixed- and Variable-Radius Plots



Contents

In 1974 the U.S. Department of Agriculture initiated the Combined Forest Pest Research and Development Program, an interagency effort that concentrated on the Douglas-fir tussock moth in the West, on the southern pine beetle in the South, and on the gypsy moth in the Northeast. The work reported in this publication was funded in whole or in part by the program. This manual is one in a series on the gypsy moth.

Gypsy Moth Egg-Mass Sampling With Fixed- and Variable-Radius Plots

by
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Introduction

To obtain reliable information about gypsy moth infestations in forested areas, a survey must be conducted. The resulting information can be used either to guide management decisions or to assess the end results of decisions. The method introduced here—sampling with fixed- and variable-radius plots, or FVP—is not intended for use in forested areas smaller than 10 acres or at egg-mass densities below 100 egg masses per acre, both of which require high sampling rates with attendant high costs. For small areas, a method based on small fixed-radius plots may be more efficient. At low population levels, a method based on pheromone trapping of adult male gypsy moths may be better if suitable techniques can be developed.

The topics discussed in this handbook include: specifications of requirements the user must make prior to a survey, how to arrive at them, and why they are important; description of the survey methods; organization and execution of the survey; and compilation of the data. The appendixes present details of various procedures.

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Survey Specifications

Objectives of the Survey

It is necessary to obtain information on all facets of the situation relevant to management decisionmaking and to avoid the collection of superfluous information. It is clear that both egg masses per acre above and below snowline and stand basal area by gypsy moth food classes are relevant information; other information may be obtained as needed. The following objectives should be adopted for the survey:

1. Estimate stand basal area per acre of live overstory trees, by gypsy moth food classes.
2. Estimate current egg masses per acre on live overstory trees above and below 1 foot from the ground.
3. Estimate current egg masses per acre *not* on live overstory trees above and below 1 foot from the ground.

Populations to be Sampled

Designation of the target population to be sampled demands careful attention if a survey is to produce reliable information. Valid inferences cannot be made about the target population if the sampled populations are not truly representative.

Ideally, the target population in gypsy moth surveys is all the egg masses within some well-defined forested area. There are two key problems in sampling these populations.

The first problem is that the boundaries of infestations are indefinite at any given time, tending to shift and coalesce over time. The second problem is the inaccessibility of parts of the populations, which takes two forms. The obvious one is remoteness from easy travel routes and trails. This can readily be overcome, at a cost, simply by insisting that the survey be designed so that each part of the population has a known chance of being sampled. The other form is that of egg masses that are hidden from the observer or are so high in trees that the sampler cannot be sure whether they are current or old. The effects of this form of the problem can be minimized, also at a cost, by painstaking work in the collection of the data, as will be discussed later.

Data to be Collected

There is a tendency in all surveys to tack on data collection requirements that are irrelevant to the purposes of the survey and that may never be subsequently utilized. It is important to verify that all the data to be collected are relevant and that no essential data are omitted. For the survey objectives previously stated, the only relevant data are the species (or food class) and the diameter at breast height (to the nearest inch) of sample trees, and the counts of egg masses on the sample trees and fixed-radius plots. The additional requirement that egg-mass counts be kept separate by height-above-ground categories is included so that future survey techniques may be made more efficient or at least of greater diagnostic value. Marginal notes about unusual conditions encountered can also be helpful.

Degree of Precision Required

Deciding upon the desired degree of precision is a troublesome aspect of any sampling procedure. It involves balancing the value of the information in the sample against the cost of obtaining it. In forestry, this can rarely be done on other than subjective grounds. While there may sometimes exist a quantitative measure of costs, there is hardly ever such a measure of derived values.

You may simplify the decisions by noting that the coefficients of variation on species composition are several times smaller than those for egg masses per acre. If a sensible precision for the latter can be established, you can reasonably assume that the precision in the other estimate will be adequate.

What about the precision in egg masses per acre? It is believed that a standard error of estimate of about 20 percent of the mean is a reasonable balance between the value of the information and its cost. Of course, meeting this standard becomes increasingly expensive as the mean density decreases, but presumably the value of the information increases correspondingly. The expense becomes prohibitive, however, at low egg-mass densities, and perhaps the suggested standard should be relaxed when egg-mass densities are expected to be in the low hundreds. In any case, the final choice of degree of precision is the responsibility of the user.

The Sampling Plan

The Frame

The sampling frame for the tree population is an infinite set of sampling points within the boundaries that limit the target population. Each point is a potential center for a sampling unit. A sampling unit consists of a variable-radius (prism) plot by which trees are selected for the sample with probability proportional to tree basal area (prism angle = 147.27 minutes, prism strength = 4.29 diopters, basal area factor = 20) and a fixed 1/200-acre plot radius (radius = 8⅓ feet) for sampling other materials. As far as we know, the original use of point sampling in egg-mass sampling was in 1973 in New York.[3]

This sampling plan was selected from among several investigated because:

1. Use of small sampling units requiring only a limited attention span encourages careful and accurate counts of egg masses by field crews. This is of overwhelming importance to the reliability of the survey.
2. Although the variation among small sampling units is greater than among large ones, the cost per unit is also proportionately less. This allows larger sample sizes drawn from sampling distributions to tend toward normality, even with strongly aggregated underlying egg-mass distributions, and at the same time maintains a given level of precision.
3. It tends to concentrate sampling effort on the largest components of the egg-mass populations. In tests of the procedure in central Pennslyvania, about 85 percent of total egg masses per acre were on live overstory trees, and the numbers in which they were found on trees varied roughly with tree size (for example, the cross-sectional area of a tree).
4. It is simple and straightforward in field operations and only slightly less so in the compilation of results. Point sampling is also compatible with defoliation surveys.

[3] New York State Department of Environmental Conservation. 1973. N.Y. For. Pest Rpt. 73 (23-24).

Selection of the Sample

The sample selection process is crucial to the success of the survey. Although a wide variety of plans exists by which information may be collected, the one used should be simple to apply in the field, meet survey specifications at reasonable cost, and, above all, yield unbiased estimates of the parameters or items to be estimated.

A simple probability sampling scheme meets these criteria. It is a plan of systematic sampling with a single random start. A uniformly spaced grid of points is laid down at random over a map of the tract to be sampled. Each point is the center for 1) a wedge prism point for selecting the live overstory sample trees and for 2) a fixed-radius ground plot to sample the egg-mass population on other materials.

To determine the *spacing* of the points in the grid it is necessary to know the area in acres of the tract and the sample size required (see following). The number of acres per sample point can then be computed. For example, if the area in the survey unit is 100 acres, and the number of sample points required is 50, then there are $100 \div 50 = 2$ acres per sampling point. This result ($2 \times 43{,}560$) is converted to 87,120 ft^2 per sampling point. For a square grid, the distance between lines and between points on a line is the square root of the per point square footage = $\sqrt{87{,}120} = 295$ ft.

Sometimes, especially for large survey units, it may be preferable to treat the area per point as a rectangle rather than a square, subject to the constraint that the distance between lines should not exceed three times the distance between points on a line. For example, suppose you found it more convenient to space the points on a line at 200 ft (this will also save almost one-third on travel time between points). Then the spacing between lines would be $87{,}120 \div 200 = 436$ ft, which is a solution that is within the constraint.

One final point: The distance between points should never be less than 100 ft. If closer, the same sample trees may be selected from two adjacent sampling points, thus weakening the sample.

TABLE 1.—*Population standard deviation and standard error of estimate for samples of size 30, at various numbers of egg masses per acre*

		Standard error of estimate	
Egg masses per acre	**Population standard deviation**	**Egg masses per acre**	**Percent of means**
25	39	7	29
50	69	13	25
75	96	18	23
100	122	22	22
150	170	31	21
200	216	39	20
300	301	55	18
400	381	70	17
500	457	83	17
600	531	97	16
800	672	123	15
1,000	808	147	15
1,200	938	171	14
1,400	1,064	194	14
1,800	1,308	239	13
2,000	1,426	260	13
2,500	1,713	313	13
3,000	1,989	363	12
3,500	2,258	412	12
4,000	2,519	460	11

Sample Size

There are two approaches to setting sample size: One is to follow our previous suggestion of a sampling error of about 20 percent of mean egg masses per acre; the other is to fine tune the sample size for the specific requirements of a given application.

For the first approach, simply set the sample size at 30 sampling points. This will give close to a 20-percent sampling error at the more critical egg mass densities, and will ease the requirement a little at lower densities and tighten it at higher densities. Columns 3 and 4 of table 1 show the confidence limits in egg masses per acre and percent of mean density, respectively, within which the actual mean will fall with chances of two in three.

To fine tune the sample size to the survey requirements, you must have specified a sampling error (SE). This is the limit within which the actual population mean is desired to fall, given the sample mean. In addition, one may also set the *confidence* that the desired outcome will occur. Confidence is expressed as the chances of a desired outcome. Chances of two in three ($t = 1$) were previously suggested, but for critical surveys you might want to increase the chances to 95 in 100 ($t=2$) or even 99 in 100 ($t=3$). As will be seen, these specifications have a substantial effect on sample size.

Also needed is an estimate of the standard deviation among sampling points in the population to be sampled. This can be obtained from an estimate of the mean egg masses per acre in the population, which may be obtained from experience or a quick preliminary survey.

In order to estimate the relationship between standard deviation (SD) and egg masses per acre (EM), twenty-one 35-acre tracts in central Pennsylvania were surveyed in 2 successive years with the following results:

$$\mathbf{SD = 2.7875(EM)^{0.82066}}$$

or

$$\mathbf{\log SD = 0.44522 + 0.82066(\log EM)}$$

The latter equation accounted for 92 percent of the variation in log SD. Some calculated SD's are shown in table 1, column 2.

Now sample size (n, the number of sampling points) can be computed from:

$$\mathbf{n} = \mathbf{t}^2 \left(\frac{\mathbf{SD}}{\mathbf{SE}}\right)^2$$

when

t = 1 for a confidence of two chances in three

t = 2 for chances of 95 in 100

t = 3 for chances of 99 in 100.

For example, suppose a preliminary survey has come up with 900 egg masses per acre and you have decided that you want a standard error of ±300 egg masses with chances 95 in 100. Then

$$\begin{aligned} \mathbf{SD} &= \mathbf{2.7875\,(900)^{0.82066}} \\ &= \mathbf{740.70} \end{aligned}$$

and

$$\begin{aligned} \mathbf{n} &= \mathbf{2^2} \left(\frac{\mathbf{740.70}}{\mathbf{300}}\right)^2 \\ &= \mathbf{25} \end{aligned}$$

The field costs of the survey will vary with the size of the tract, size of the trees, egg-mass density, and roughness of the terrain and undergrowth. Costs thus far have not been under operational conditions, but the estimate is roughly 1 man-hour per point under usual conditions, a generous allowance for careful work.

Carrying Out the Survey

When the sampling plan is completed, including mapped sample-point locations, the survey may be carried out. This section deals with location of the sample points, crew organization, order of work, and timing of surveys.

Before launching into these matters, you need to think about planning the field work on a day-to-day basis. The importance of prior planning, to assure that the survey is well founded to accomplish the objectives successfully, has been stressed. No less important are the careful planning and execution of the field work. If survey results are to be meaningful, the field data must be accurate. If the costs are to be reasonable, the work must be done efficiently but with care. Planning each day's work in advance, maintaining and replacing equipment, and editing of field forms before leaving a field point are some of the ways by which good results can be obtained.

One final matter of importance is the effect of weather conditions on egg-mass visibility. The weather class should be recorded on the field forms (appendix A), and if at all possible, the survey should be conducted only when the weather class is excellent or fair.

Location of Sample Points

Prior to the start of the survey, the supervisor must convert the set of sampling points on the survey unit map to instructions for locating the points on the ground. To do this, select a nearby point such as a road or trail intersection that is easily identified both on the ground and on the map. From this point, plot a simple traverse to the starting point of the survey, then determine from the map the bearing or azimuth of the lines of sampling points and plot the offsets from one line to another (fig. 1).

In the field, the supervisor must emphasize careful compass work and horizontal tape measurement. Ideally, the lines will be run with a staff compass, a two-chain tape with topographic trailer, and a topographic Abney level. Such techniques are particularly appropriate in rough, hilly country where the tract boundaries are not marked on the ground. In relatively level country, horizontal chaining by breaking chain when necessary without using the level and trailer is acceptable. Horizontal chaining may also be done where visibility is poor and short line sights must be used.

Crew Organization

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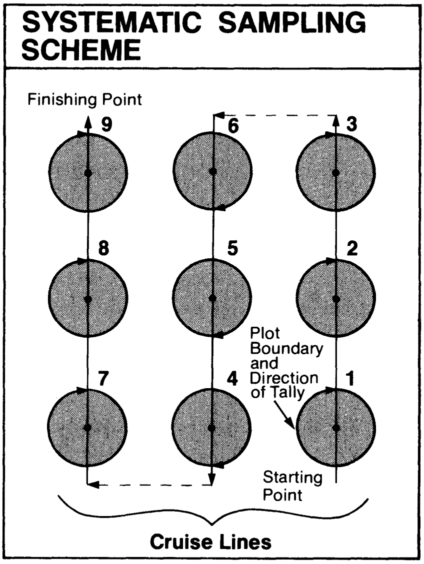

Figure 1.—Schematic of sampling-point layout showing order of travel to points. Also indicated is the pattern of search for egg masses at the points.

A crew of three persons provides the best continuity and speed in the work. A two-person crew can be used if necessary but is awkward because of the multiplicity of jobs.

The jobs, especially the egg-mass counting, tend to be tedious and should be rotated frequently among crew members. Rotating job responsibilities at the completion of a working unit, or every 4 hours, is sufficient to reduce errors caused by monotony or job fatigue. All crew members, therefore, must be well trained and proficient in all the jobs. At any given time, the tally man should check the other crew members for oversights and gross mistakes.

If more than one crew is available for a survey, the crews should be assigned adjacent survey lines and should leapfrog each other in completing the survey. This will distribute individual crew biases evenly over the tract and will facilitate the work of the supervisor. It will also permit the detection and estimation of any serious crew bias.

Timing of the Field Work

We have found that the survey can be conducted equally well before or after leaf fall. The survey season can be extended from roughly the first of August (after moth flight) throughout the winter, depending upon snow and weather conditions. The bottleneck imposed by waiting until the leaves are down to start field work can be eliminated.

Estimates of egg masses per acre on trees, based on counts made on sample trees in August and September, were compared with estimates based on counts made at the same sampling points in November. The study was done in central Pennsylvania on eight separate 35-acre survey units, each of which contained 40 sampling points.

The within-unit correlations of fall and summer adjusted counts were high, ranging from 0.82 to 0.95 (table 2). Evidently the fall and summer counts were, in general, consistent with one another. However, in half the units, the fall/summer differences in estimated egg masses per acre were large and significantly different from zero, while half were small and not significantly different from zero. The large differences ranged from 22 to 34 percent of the fall egg-mass estimates, but the small differences were only 3 to 7 percent of the fall means.

No patterns were found in the data that might explain the large differences. Certainly the greater visibility in the fall and the loss of egg-mass color in the fall are compensating factors. Most likely, however, the differences are due to counting errors on both occasions and simply point up the need for careful field work. Careless count-

TABLE 2.—*Comparison of fall and summer estimates of total egg masses per acre on overstory trees* [1]

Survey unit	Fall egg masses per acre	Correlation coefficient	Summer egg masses per acre	Difference: Egg masses per acre
1	1,325	0.95	1,639	–314
2	300	.82	322	–22
3	1,322	.94	1,394	–72
4	155	.89	102	53
5	806	.89	620	186
6	701	.93	667	34
7	458	.92	473	–15
13	605	.88	472	133

[1] Number of points per survey is 40.
[2] Significantly different from zero with P$\leqq$.05.

ing can easily overpower counting errors due to season.

In half the survey units, the fall estimates of egg masses per acre were the larger ones; in the other half, the summer estimates were larger. The average difference over all eight tracts was just two egg masses per acre—in favor of the summer estimates; hence the conclusion that surveys can begin as soon as egg-mass deposition is complete.

A survey with foliage present is more time consuming than one in the absence of foliage. The extra time is required for use of binoculars because of a reduction in bole and crown visibility, and to insure careful viewing for a maximum quality egg-mass count.

Percent	Standard deviation of the difference in egg masses per acre	t
−24	939	[2]2.115
−7	264	.528
−5	618	.737
34	149	[2]2.253
23	467	[2]2.517
5	330	.650
3	303	.313
22	275	[2]3.053

Fixed-Radius Plots to Sample Nonoverstory Egg Masses

The fixed-radius plot is used to survey the egg masses occurring in strata other than the live overstory trees. The best procedure is first to establish the fixed-radius plot and then to make the egg-mass counts before the plot is disturbed.

For uniformity, always start the egg-mass count in line with the direction of travel. The tally person stands over the center point and the person doing the count goes out to the plot perimeter, a distance of 8⅓ ft. Use a tape measure or measuring stick (fig. 2) for accuracy and be sure the center point is not allowed to move. The 8⅓-foot measure is the radius of a 1/200-acre plot, which is the largest plot size that is both convenient and conducive to accurate, adequately precise counts.

Traveling in a clockwise direction, the person making the egg-mass counts uses the tape or measuring stick to mark the territory covered. The area is examined closely during the frequent trips back and forth from the perimeter to the center point.

All objects and materials within the plot are examined for egg masses *except* the live overstory trees exposed to direct skylight (dominant, codominant, and intermediate trees). Count all egg masses on dead and understory trees with stump centers in the plot. For all other objects, only egg masses within the plot boundary are included in the count.

In counting nontree egg masses, experience is helpful in learning where the egg masses are likely to be found. Upper surfaces of brush, sticks, logs, and rotten moist materials are the least likely areas; more favorable locations include the crotches of understory trees and brush, and the undersides of logs, branches, and rocks.

At very low densities, the egg masses tend to be deposited on the ground cover. The ground cover, therefore, becomes proportionally more important with a decrease in density. With moderate to high densities, the stems of brush are more favorable depositories. The undersides of rocks and branches are used in all population densities.

2A

2B

Figure 2, *A* and *B*.—Using a measuring stick to lay out 8⅓-foot radius of fixed ground plot.

Prism Points to Sample Overstory Tree Population

After completing the data collection for the fixed-radius plot, the collection of data for the prism point can begin. *The prism point is the center point of the fixed-radius plot.* Utilizing the procedures in appendix C, the sample trees are now selected. As with the fixed-radius plot, start the selection in line with the direction of travel and rotate in a clockwise direction to locate the sample trees, *being sure always to keep the wedge prism over the center point* (fig. 3).

After a candidate tree is selected for the sample, check the tree condition. If the tree is not alive, or is not receiving direct skylight on its crown (that is, in the open-grown, dominant, codominant, or intermediate crown class), reject the tree as a sample and go on to the next one.

If the tree is acceptable as a sample, carefully check the prism sighting and be sure to measure the distance to the tree from the center point, if it is a borderline tree. Then, if the tree is "in," record the tree species (or food class) and d.b.h. to the nearest inch (see appendix A for codes). Finally, proceed with the egg-mass census of the tree.

For summer counts (foliage present), binoculars are a necessity. With fall counts (after leaves have fallen), the naked eye can be used for portions of the bole. At moderate to high egg-mass densities, it is best to tally the bole, then tally the limbs and branches. At low densities, it is possible to tally the tree totally, keeping the crown and bole counts separate, then noting the final counts (by height class) on the tally sheet.

3A

3B

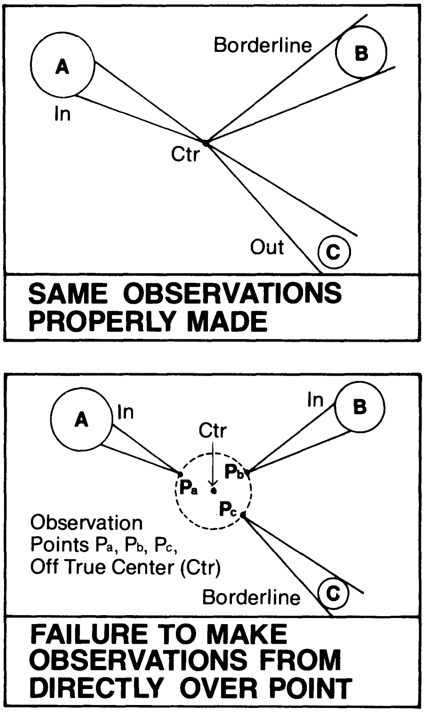

Figure 3.—Prism sighting technique: *A,* Proper technique; *B,* improper technique.

With small trees (4 inches d.b.h. and smaller), counting on two faces is usually sufficient. Larger trees can be surveyed by using three faces. Be careful not to overlap the faces and cause an overcoverage (overcount). If only two faces are tallied, an undercoverage (undercount) error is made. For very large trees, it may be necessary to count more than three faces for the total coverage (fig. 4).

For a census of egg masses deposited on the crown, it is best to divide the crown by branch clumps, if such clumping occurs on the tree. If clumping does not occur, then divide the tree into faces. As with the bole, caution must be exercised in order to avoid either undercoverage or overcoverage. Because of the presence of foliage during a summer census, dividing the tree into more faces may be desirable to keep any one working area a more manageable size. The purpose is to count the live overstory tree egg masses as accurately as possible. Too many faces cause overcoverage, whereas too few faces cause undercoverage.

Once the data for the prism point have been collected, remove the center pin and continue to the next sample point. The procedures just described in this section are repeated for all sample points in the survey.

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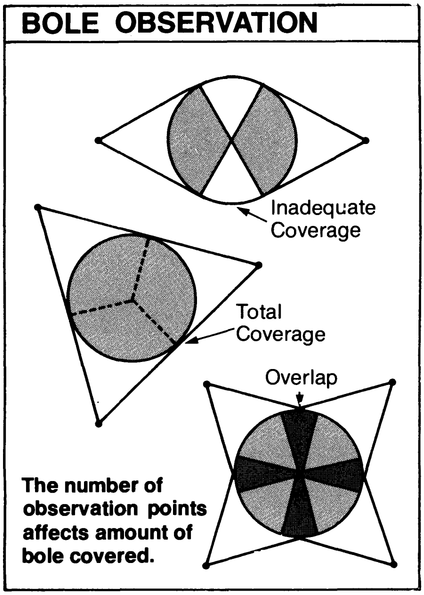


Figure 4.—Schematic illustrating in vertical projection how the tree bole should be laid off in faces for counting egg masses.

Compilation of the Data

Now you must calculate the estimated means and standard errors for the variables of interest—that is, basal area per acre and total egg masses per acre, from the sample data. An example of the calculations using a small illustrative sample is given in appendix B.

In the formulas that follow, the sample data are symbolized in the following manner:

x_i = egg mass count in the *i*th 1/200-acre fixed plot
y_{ij} = egg mass count on the *j*th sample tree at the *i*th prism point
d_{ij} = d.b.h. of the *j*th sample tree at the *i*th prism point in inches
k_i = number of sample trees at the *i*th prism point
n = number of 1/200-acre fixed plots and prism points

and

$\overset{n}{\underset{i=1}{S}}$ = sum of the n terms which follow this symbol

Basal Area Estimates

Total basal area per acre in the overstory is estimated simply as:

$$\textbf{Basal area per acre} = 20\left(\frac{\overset{n}{\underset{i=1}{S}} k_i}{n}\right)$$

The standard error of estimated basal area per acre is:

$$20\sqrt{\frac{\overset{n}{\underset{i=1}{S}} k_i^2 - \left(\frac{\overset{n}{\underset{i=1}{S}} k_i}{n}\right)^2}{n(n-1)}}$$

To estimate the basal area by food classes, just substitute the number of trees in a food class at each point for k_i; repeat the calculation for each food class.

Fixed 1/200-Acre Plot Estimates of Egg Masses per Acre

Mean number of egg masses per acre ($\bar{x}$):

$$\bar{x} = 200\left(\frac{\sum_{i=1}^{n} x_i}{n}\right)$$

Variance of the mean number of egg masses per acre ($V_{\bar{x}}$):

$$V_{\bar{x}} = 200^2\left(\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}\right)$$

$$= 200^2\left(\frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}}{n(n-1)}\right)$$

Prism Point Estimates of Egg Masses per Acre

Weighted egg-mass count at a point ($y_{i.}$):

$$y_{i.} = \sum_{j=1}^{k_i}\left(\frac{y_{ij}}{d_{ij}^2}\right)$$

Mean number of egg masses per acre ($\bar{y}$):

$$\bar{y} = 3667\left(\frac{\sum_{i=1}^{n} y_{i.}}{n}\right)$$

Variance of the mean number of egg masses per acre ($V_{\bar{y}}$):

$$V_{\bar{y}} = 3667^2\left(\frac{\sum_{i=1}^{n}(y_{i.} - \bar{y})^2}{n(n-1)}\right)$$

$$= 3667^2\left(\frac{\sum_{i=1}^{n} y_{i.}^2 - \frac{\left(\sum_{i=1}^{n} y_{i.}\right)^2}{n}}{n(n-1)}\right)$$

Estimates of Total Egg Masses per Acre

Mean total egg masses per acre (EM):

$$\mathbf{EM} = \bar{x} + \bar{y}$$

Variance of the mean total number of egg masses per acre ($V_{\bar{x}+\bar{y}}$):

$$V_{\bar{x}+\bar{y}} = (V_{\bar{x}} + V_{\bar{y}} + 2COV_{\bar{x}\bar{y}})$$

where the covariance term is computed as:

$$COV_{\bar{x}\bar{y}} = (200)\,(3667)\left(\frac{\displaystyle\mathop{S}_{i=1}^{n} x_i y_{i.} - \frac{\left(\displaystyle\mathop{S}_{i=1}^{n} x_i\right)\left(\displaystyle\mathop{S}_{i=1}^{n} y_{i.}\right)}{n}}{n(n-1)}\right)$$

Standard error of the estimate ($SE_{\bar{x}+\bar{y}}$):

$$SE_{\bar{x}+\bar{y}} = \sqrt{V_{\bar{x}+\bar{y}}}$$

Appendixes

A—Recording Instructions and Codes

Sample Field Form for the Data at a Sampling Point

Region	Study	Unit	Line	Point	Mo./Day/Yr.

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6 +

Tree	Spec	DBH	New Egg Masses				
			0-1	1-3	3-6	6 +	Crwn
01							
02							
03							
04							
05							
06							
07							
08							
09							
10							

NOTES:

Weather Classes

Weather variables that affect the visibility of pupae and egg masses should be noted.

Excellent—Sky clear with little or no haze or overcasting clouds. Sunlight diffuse ("noonday" conditions) with little or no shadows or direct blinding sunlight. Contrast high (treetops dark with blue sky background).

Fair—Sky mostly clear with clouds present (cloud cover between one-third and two-thirds). Sunlight more directional and may cause shadows and/or direct rays. (Generally, the sun is approximately at a 45° angle.) Contrast medium (treetops dark with cloudy sky background).

Poor—Sky is overcast (cloud cover more than two-thirds) or a heavy haze present. Sun is below a 45° angle, causing heavy shadows and/or blinding directional sunlight. Contrast low (treetops dark with gray overcast sky background).

Precipitation—Rain, snow, sleet, etc.

Wet bark—With or without active precipitation.

Limiting Distance for Basal Area Factor 20 by Diameter at Breast Height[1]

Diameter at Breast Height, in Inches	.0	.1	.2
2	3.89	4.08	4.28
3	5.83	6.03	6.22
4	7.78	7.97	8.17
5	9.72	9.92	10.11
6	11.67	11.86	12.06
7	13.61	13.81	14.00
8	15.56	15.75	15.95
9	17.50	17.70	17.89
10	19.45	19.64	19.83
11	21.39	21.58	21.78
12	23.33	23.53	23.72
13	25.28	25.47	25.67
14	27.22	27.42	27.61
15	29.17	29.36	29.56
16	31.11	31.31	31.50
17	33.06	33.25	33.45
18	35.00	35.20	35.39
19	36.95	37.14	37.33
20	38.89	39.08	39.28
21	40.83	41.03	41.22
22	42.78	42.97	43.17
23	44.72	44.92	45.11
24	46.67	46.86	47.06
25	48.61	48.81	49.00
26	50.56	50.75	50.95
27	52.50	52.70	52.89
28	54.45	54.64	54.84
29	56.39	56.59	56.78
30	58.34	58.53	58.72
31	60.28	60.47	60.67
32	62.22	62.42	62.61
33	64.17	64.36	64.56
34	66.11	66.31	66.50
35	68.06	68.25	68.45
36	70.00	70.20	70.39
37	71.95	72.14	72.34
38	73.89	74.09	74.28
39	75.84	76.03	76.22
40	77.78	77.98	78.17

[1] To be included in the sample, a tree of given d.b.h. must have its center at breast height within the indicated horizontal limiting distance from the sampling point.

.3	.4	.5	.6	.7	.8	.9
Limiting Distance in Feet = 1.9445 × *d.b.h. in Inches*						
4.47	4.67	4.86	5.06	5.25	5.44	5.64
6.42	6.61	6.81	7.00	7.19	7.39	7.58
8.36	8.56	8.75	8.94	9.14	9.33	9.53
10.31	10.50	10.69	10.89	11.08	11.28	11.47
12.25	12.44	12.64	12.83	13.03	13.22	13.42
14.19	14.39	14.58	14.78	14.97	15.17	15.36
16.14	16.33	16.53	16.72	16.92	17.11	17.31
18.08	18.28	18.47	18.67	18.86	19.06	19.25
20.03	20.22	20.42	20.61	20.81	21.00	21.20
21.97	22.17	22.36	22.56	22.75	22.95	23.14
23.92	24.11	24.31	24.50	24.70	24.89	25.08
25.86	26.06	26.25	26.45	26.64	26.83	27.03
27.81	28.00	28.20	28.39	28.58	28.78	28.97
29.75	29.95	30.14	30.33	30.53	30.72	30.92
31.70	31.89	32.08	32.28	32.47	32.67	32.86
33.64	33.83	34.03	34.22	34.42	34.61	34.81
35.58	35.78	35.97	36.17	36.36	36.56	36.75
37.53	37.72	37.92	38.11	38.31	38.50	38.70
39.47	39.67	39.86	40.06	40.25	40.45	40.64
41.42	41.61	41.81	42.00	42.20	42.39	42.58
43.36	43.56	43.75	43.95	44.14	44.33	44.53
45.31	45.50	45.70	45.89	46.08	46.28	46.47
47.25	47.45	47.64	47.83	48.03	48.22	48.42
49.20	49.39	49.59	49.78	49.97	50.17	50.36
51.14	51.34	51.53	51.72	51.92	52.11	52.31
53.09	53.28	53.47	53.67	53.86	54.06	54.25
55.03	55.22	55.42	55.61	55.81	56.00	56.20
56.97	57.17	57.36	57.56	57.75	57.95	58.14
58.92	59.11	59.31	59.50	59.70	59.89	60.09
60.86	61.06	61.25	61.45	61.64	61.84	62.03
62.81	63.00	63.20	63.39	63.59	63.78	63.97
64.75	64.95	65.14	65.34	65.53	65.72	65.92
66.70	66.89	67.09	67.28	67.47	67.67	67.86
68.64	68.84	69.03	69.22	69.42	69.61	69.81
70.59	70.78	70.97	71.17	71.36	71.56	71.75
72.53	72.72	72.92	73.11	73.31	73.50	73.70
74.47	74.67	74.86	75.06	75.25	75.45	75.64
76.42	76.61	76.81	77.00	77.20	77.39	77.59
78.36	78.56	78.75	78.95	79.14	79.34	79.53

Breakdown of Encountered Tree Species into Five Food-Preference Classes[4]

I. MOST PREFERRED

A. Class 1

802 *Quercus alba* (white oak)
832 *Quercus prinus* (chestnut oak)

B. Class II

806 *Quercus coccinea* (scarlet oak)
816 *Quercus ilicifolia* (bear oak)
833 *Q. rubra* (northern red oak)
837 *Q. velutina* (black oak)

C. Class III

350 *Alnus spp.* (alder)
375 *Betula papyrifera var. papyrifera* (paper birch)
379 *Betula populifolia* (gray birch)
660 *Malus spp.* (apple)
743 *Populus grandidentata* (bigtooth aspen)
746 *Populus tremuloides* (quaking aspen)
951 *Tilia americana* (American basswood)

II. INTERMEDIATE

Class IV

316 *Acer rubrum var. rubrum* (red maple)
318 *Acer saccharum* (sugar maple)
331 *Aesculus glabra* (Ohio buckeye)
999 *Amelanchier canadensis* (amelanchier)
391 *Carpinus caroliniana* (American hornbean)
402 *Carya cordiformis* (bitternut hickory)
403 *Carya glabra* (pignut hickory)
407 *C. ovata* (shagbark hickory)
409 *C. tomentosa* (mockernut hickory)
421 *Castanea dentata* (American chestnut)
462 *Celtis occidentalis* (hackberry)

[4] Food class designation from: Houston, D. R., and H. T. Valentine. 1977. Comparing and predicting forest stand susceptibility to gypsy moth. Can. J. For. Res. Species codes and names from Northeastern Forest Survey Field Manual. U.S. Dept. Agric., For. Serv., Northeastern For. Exp. Stn.

Class IV (cont'd)

491 *Cornus florida* (flowering dogwood)
521 *Diospyros virginiana* (common persimmon)
531 *Fagas grandifolia* (American beech)
999 *Hamamelis virginiana* (witch hazel)
601 *Juglans cinerea* (butternut)
602 *Juglans nigra* (black walnut)
651 *Magnolia acuminata* (cucumber tree)
693 *Nyssa sylvatica var. sylvatica* (black tupelo)
701 *Ostrya virginiana* (hophornbeam)
123 *Pinus pungens* (table mountain pine)
125 *Pinus resinosa* (red pine)
126 *P. rigida* (pitch pine)
129 *P. strobus* (eastern white pine)
132 *P. virginiana* (Virginia pine)
762 *Prunus serotina* (black cherry)
824 *Quercus marilandica* (blackjack oak)
835 *Quercus stellata var. stellata* (post oak)
931 *Sassafras albidum* (sassafras)
261 *Tsuga canadensis* (eastern hemlock)
972 *Ulmis americana* (American elm)
975 *Ulmis rubra* (slippery elm)

III. LEAST PREFERRED

Class V

541 *Fraxinus americana* (white ash)
068 *Juniperus virginiana* (eastern redcedar)
621 *Liriodendron tulipifera* (yellow-poplar)
097 *Picea rubens* (red spruce)
130 *Pinus sylvestris* (scotch pine)
901 *Robinia pseudoacacia* (black locust)
999 *Rhus spp.* (sumac)

B—A Data Compilation Example

This example is intended to help the serious reader through the basic calculations necessary for the compilation of the egg-mass survey data.

A sample survey of six sampling points is the basis for the exercise and is presented on field forms that are also used as preliminary worksheets for the summary of the sampling point data. With the field forms as a guide, individual estimates are made: basal area per acre of overstory trees and its standard error; the egg masses per acre for overstory trees and its variance; the egg masses per acre on other materials and its variance; and finally, the total egg masses per acre and its standard error. Similar calculations using only egg masses in the 0–1 foot height class will lead to estimates of egg masses per acre for that portion of the population. The first step is to summarize the egg-mass data on each tally sheet to obtain the point values, $y_{i.}$ (weighted egg masses on overstory trees) and x_i (egg masses on other materials).

The x_i is simply the sum of the egg masses tallied on the 1/200-acre plot by height above ground. For example, on the tally sheet for point one,
$x_1 = 0 + 0 + 0 + 0 = 0$

The $y_{i.}$ is a little more complicated:

$$y_{i.} = \underset{j=1}{\overset{k_i}{S}} \left(\frac{y_{ij}}{d_{ij}^2} \right)$$

Where k_i is the number of trees at a point, y_{ij} is the sum of egg masses on a tree (as for x_i above) and d_{ij} is the d.b.h. of the tree. For the first point in the example we have:

$$y_{i.} = \frac{2}{10^2} + \frac{0}{12^2} = 0.0200$$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	1	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6 +
	2	1	✓					0	0	0	0

$x_1 = 0$

Tree	Spec	d_{ij} DBH	New Egg Masses					y_{ij}	$\frac{y_{ij}}{d_{ij}^2}$
			0-1	1-3	3-6	6 +	Crwn		
01	806	10	0	1	0	0	1	2	0.0200
02	806	12	0	0	0	0	0	0	0
03									
04									
05									
06									
07									
08									
09									
10									

NOTES:

$y_{1.} = 0.0200$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	2	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6 +
	5	1	✓					0	0	0	0

$X_2 = 0$

Tree	Spec	d_{2j} DBH	New Egg Masses					y_{2j}	$\frac{y_{2j}}{d_{2j}^2}$
			0-1	1-3	3-6	6 +	Crwn		
01	316	8	0	0	0	0	0	0	0
02	802	9	1	0	2	1	0	4	0.0494
03	832	11	0	0	0	0	0	0	0
04	802	12	0	0	1	1	9	11	0.0764
05	802	9	0	1	0	1	0	2	0.0247
06									
07									
08									
09									
10									

NOTES:

$y_{2.} = 0.1505$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	3	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6+
	4	1	✓					0	0	0	0

$x_3 = 0$

Tree	Spec	d_{3j} DBH	New Egg Masses					y_{3j}	$\frac{y_{3j}}{d_{3j}^2}$
			0-1	1-3	3-6	6+	Crwn		
01	802	7	0	0	0	0	0	0	0
02	806	7	0	0	0	0	0	0	0
03	802	5	1	0	1	0	2	4	0.1600
04	802	13	0	0	0	1	6	7	0.0414
05									
06									
07									
08									
09									
10									

NOTES:

$y_{3.} = 0.2014$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	4	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6+
	5	1	✓					0	0	0	0

$x_4 = 0$

Tree	Spec	d_{4j} DBH	New Egg Masses 0-1	1-3	3-6	6+	Crwn	y_{4j}	$\frac{y_{4j}}{d_{4j}^2}$
01	806	13	0	0	0	0	7	7	0.0414
02	802	7	0	0	0	0	0	0	0
03	806	8	1	0	0	0	0	1	0.0156
04	802	8	0	0	0	0	1	1	0.0156
05	802	9	0	0	1	0	3	4	0.0494
06									
07									
08									
09									
10									

NOTES:

$y_{4.} = 0.1220$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	5	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6+
	3	1	✓					1	0	0	0

$x_s = 1$

Tree	Spec	d_{sj} DBH	New Egg Masses					y_{sj}	$\frac{y_{sj}}{d_{sj}^2}$
			0-1	1-3	3-6	6+	Crwn		
01	316	7	0	0	0	0	0	0	0
02	802	6	0	0	1	0	0	1	0.0278
03	802	13	0	0	0	0	2	2	0.0118
04									
05									
06									
07									
08									
09									
10									

NOTES:

$y_{s.} = 0.0396$

Region	Study	Unit	Line	Point	Mo./Day/Yr.
		26	1	6	10/7/76

Card	No. Trees	Crew	EM Visibility					New Egg Masses			
			Excel	Fair	Poor	Prec	Wet	0-1	1-3	3-6	6+
	6	1	✓					0	0	0	0

$x_6 = 0$

Tree	Spec	d_{6j} DBH	New Egg Masses 0-1	1-3	3-6	6+	Crwn	y_{6j}	$\frac{y_{6j}}{d_{6j}^2}$
01	802	11	0	0	0	0	7	7	0.0579
02	833	13	0	1	0	0	0	1	0.0059
03	802	12	0	0	0	1	5	6	0.0417
04	802	12	0	0	0	0	0	0	0
05	802	10	0	0	0	0	0	0	0
06	802	12	0	0	0	0	1	1	0.0069
07									
08									
09									
10									

NOTES:

$y_{6.} = 0.1124$

Egg Masses per Acre on Overstory Trees (Points)

The next step is to produce the estimate of the egg masses per acre on overstory trees (points). The estimate is:

$$\bar{y} = 3667 \left(\frac{\sum_{i=1}^{n} y_{i.}}{n} \right)$$

when, using the $y_{i.}$ summarized on each tally sheet,

$$\sum_{i=1}^{n} y_{i.} = 0.0200 + 0.1505 + 0.2014 + 0.1220 + 0.0396 + 0.1124$$

$$= 0.6459$$

so that

$$\bar{y} = 3667 \left(\frac{0.6459}{6} \right) = 395 \text{ egg masses per acre.}$$

The variance of the estimate (to be used in calculating the standard error of the total) is:

$$V_{\bar{y}} = 3667^2 \left(\frac{\sum_{i=1}^{n} y_{i.}^2 - \frac{\left(\sum_{i=1}^{n} y_{i.}\right)^2}{n}}{n(n-1)} \right)$$

when

$$\sum_{i=1}^{n} y_{i.}^2 = 0.0200^2 + 0.1505^2 + 0.2014^2 + 0.1220^2 + 0.0396^2 + 0.1124^2$$

$$= 0.0927$$

and

$$\sum_{i=1}^{n} y_{i.} = 0.6459 \text{ as above}$$

so that

$$V_{\bar{y}} = 3667^2 \left(\frac{0.0927 - \frac{0.6459^2}{6}}{6(6-1)} \right)$$

$$= 10{,}385.$$

Egg Masses per Acre on Other Materials (Plots)

Now we can carry out the analogous operations to estimate egg masses per acre on other materials (plots). The estimate is:

$$\bar{x} = 200\left(\frac{\sum_{i=1}^{n} x_i}{n}\right)$$

where, using the x_i summarized on the tally sheet

$$\sum_{i=1}^{n} x_i = 0+0+0+0+1+0 = 1$$

so that

$$\bar{x} = (200)\frac{1}{6} = 33 \text{ egg masses per acre}$$

The variance of the estimate (which is also used in calculating the standard error of the total) is

$$V\bar{x} = 200^2\left(\frac{\sum_{i=1}^{n} x_i^2 - \left(\frac{\sum_{i=1}^{n} x_i}{n}\right)^2}{n(n-1)}\right)$$

where

$$\sum_{i=1}^{n} x_i = 0^2+0^2+0^2+0^2+1^2+0^2 = 1$$

and

$$\sum_{i=1}^{n} x_i = 1 \text{ as above}$$

so that

$$V_{\bar{x}} = 200^2\left(\frac{1-\frac{(1)^2}{6}}{6(6-1)}\right)$$

$$= 1111.$$

Total Egg Masses per Acre (Points and Plots)

The estimate of total egg masses per acre is simply the sum of two previous estimates:

$$\mathbf{TOT} = \bar{x} + \bar{y}$$
$$= 33 + 395 = 428 \text{ egg masses per acre}$$

The standard error of the,estimate is

$$SE_{\bar{x}+\bar{y}} = \pm\sqrt{V_{\bar{x}} + V_{\bar{y}} + 2COV_{\bar{x}\bar{y}}}$$

where $V_{\bar{x}}$ and $V_{\bar{y}}$ have been computed above and

$$COV_{\bar{x}\bar{y}} = (200)(3667)\left(\frac{\sum_{i=1}^{n} x_i y_{i.} - \dfrac{\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_{i.}\right)}{n}}{n(n-1)}\right)$$

where

$$\sum_{i=1}^{n} x_i y_{i.} = 0 \times 0.200 + 0 \times 0.1505 + 0 \times 0.2014 + 0 \times 0.1220 + 1 \times 0.0396 + 0 \times 0.1124 = 0.0396$$

so that

$$COV_{\bar{x}\bar{y}} = (200)(3667)\left(\frac{0.0396 - \dfrac{(1)(0.6459)}{6}}{6(6-1)}\right)$$
$$= -1{,}664$$

then

$$SE_{\bar{x}+\bar{y}} = \sqrt{1{,}111 + 10{,}385 + 2 \times (-1{,}664)}$$

$$= \pm 90 \text{ egg masses per acre.}$$

Egg Masses per Acre for Subtotals

If estimates are required for subtotals (say egg masses per acre less than 1 ft from the ground), it is necessary only to go back to the tally sheet, define x_i and y_{ij} in those terms, and then redo all the above calculations. The results:

$\bar{y} = 45$ $\bar{x} = 33$

$V_{\bar{y}} = 503$ $COV_{\bar{x}\bar{y}} = -301$ $V_{\bar{x}} = 1{,}111$

$TOT = 78$ $SE_{\bar{x}+\bar{y}} = \pm 32$

Basal Area per Acre in Overstory Trees

The basal area per acre in overstory trees depends only on the numbers of such trees, k_i, tallied at each sampling point:

$$\mathbf{BA} = 20 \left(\frac{\sum_{i=1}^{n} k_i}{n} \right)$$

where

$$\sum_{i=1}^{n} k_i = 2+5+4+5+3+6 = 25$$

so that

$$\mathbf{BA} = 20\left(\frac{25}{6}\right) = 83.$$

The standard error of the basal area estimate is

$$SE_{BA} = 20 \sqrt{\left(\frac{\sum_{i=1}^{n} k_i^2 - \frac{\left(\sum_{i=1}^{n} k_i\right)^2}{n}}{n(n-1)} \right)}$$

where

$$\sum_{i=1}^{n} k_i^2 = 2^2 + 5^2 + 4^2 + 5^2 + 3^2 + 6^2 = 115$$

and

$$\sum_{i=1}^{n} k_i = 25 \text{ as above}$$

so that

$$SE_{BA} = \pm 20 \sqrt{\left(\frac{115 - \frac{25^2}{6}}{6(6-1)} \right)}$$

$$= \pm 12.$$

For estimates of basal area by species or gypsy moth food class, simply go back to the tally sheets, redefine the k_i accordingly, and repeat the calculations for each class. For food classes, the results from the example are:

Food class	Species included	Basal area	Standard error of basal area
1	802,832	57	14
2	806,833	20	7
3	-	0	0
4	316	7	4
5	-	0	0

Training Exercise in Use of Wedge Prism

A short training exercise in use of the wedge prism helps to eliminate human error during an actual survey.

(1) Carefully measure the d.b.h. of a tree to the nearest tenth of an inch, using a diameter tape. Take the reading at a right angle to the line of sight. Refer to figure 5 for the correct procedure.

(2) From Appendix A, use the table "Horizontal Limiting Distance in Feet For Trees of a Given Diameter" to determine the "critical distance" (the maximum distance for a given diameter tree for which the tree is considered "in" or is tallied). Determine the critical distance from the table. Critical distance is measured from the center of the tree at d.b.h. Measure this distance and mark the point.

5A

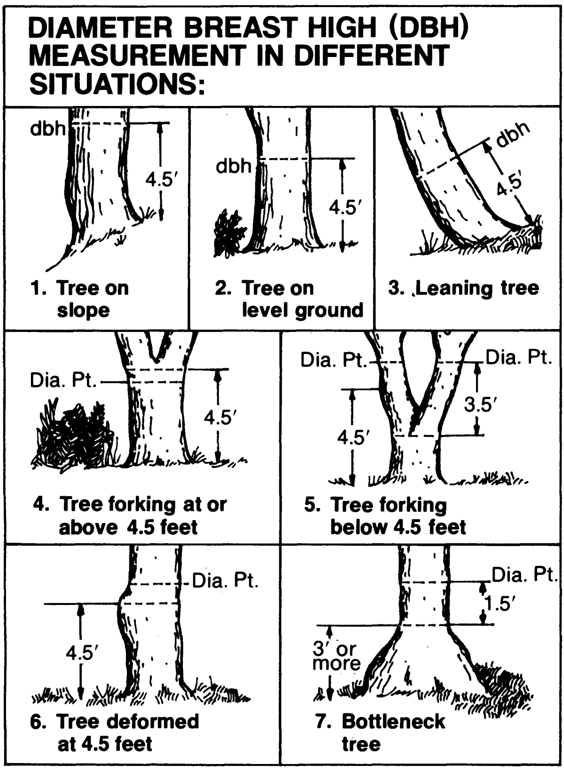
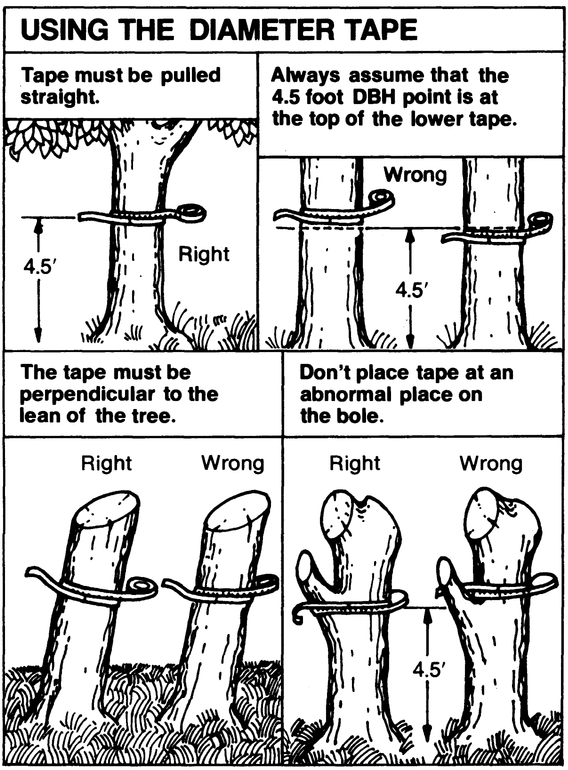


Figure 5, *A* and *B*.—Procedures for establishing diameter at breast height (d.b.h.). From Northeastern Forest Survey Field Manual. U.S. Dept. Agric., For. Serv., Northeastern For. Exp. Stn.

(3) In using a wedge prism, it is critical to hold the prism over the center point or, in this exercise, over the critical distance point. The distance between the observer's eye and the prism is not critical; therefore, the observer can hold the prism wherever it is most comfortable (e.g., arms length or one-half arm's length). From the critical distance point, the tree will appear to be borderline; that is, the offset portion of the tree will just touch the tree (fig. 6). As the observer moves closer to the tree (from the critical distance point) it becomes more "in." As the observer moves further from the tree (away from the critical distance point) it becomes more "out." Because of the differences in observer eyesight, it is always best to measure the critical distance for all borderline trees.

5B



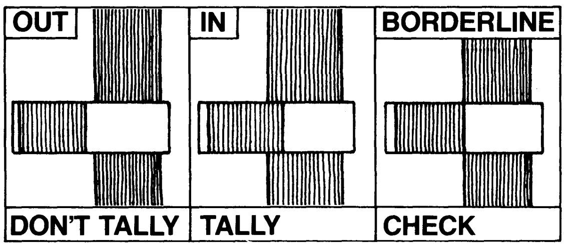
If the tree leans, the prism can be rotated so it is parallel to the tree (fig. 7). *If the lean is either away or toward the observer, it is best to measure the distance from the point to the center of the tree at d. b. h., then refer to the critical distance table to see if the tree is either "in" or "out."*

The importance of keeping the prism directly over the point is graphically illustrated in figure 8.

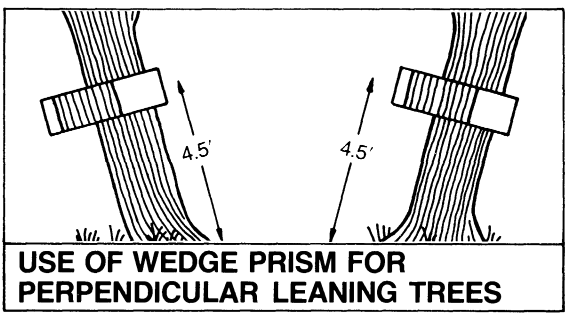
Figure 6.—Schematic of prism use in the selection of sample trees.

Figure 7.—Schematic showing rotation of prism for selection of leaning trees.

6



7



8

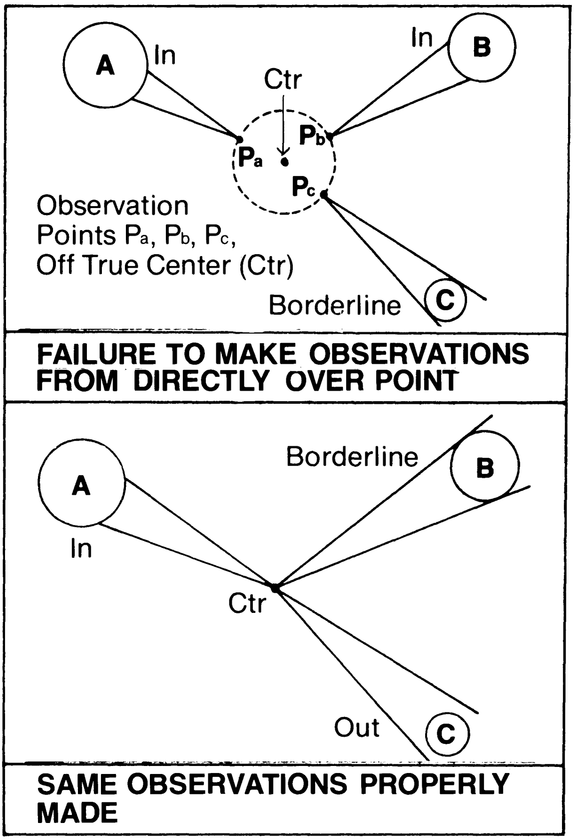
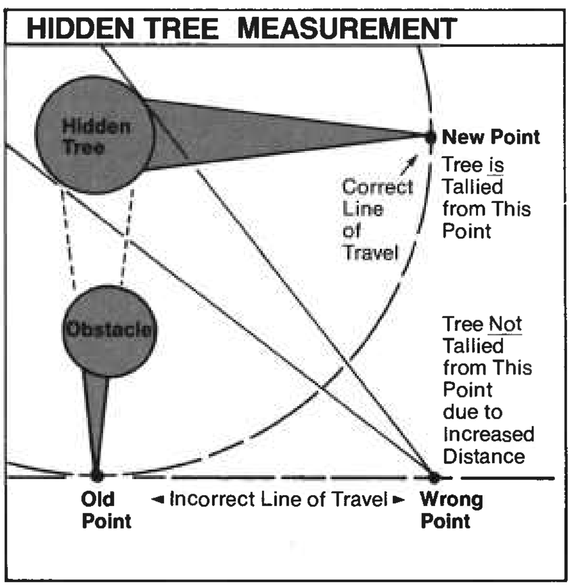


Figure 8.—Effect of prism position on selection of sample trees. Note that when the prism is circled around the sampling point, tree B becomes "in" instead of "borderline" and tree C becomes "borderline" instead of "out."

(4) Repeat step 3 using trees of various diameter and tree species with rough and smooth bark. Repeat the procedure where the brush or reproduction partially obscures the sample tree. If a tree is completely obscured from sight, the center point may be moved by keeping the distance from the tree to the old center point equal to the distance between the tree and the new point (fig. 9).



9

Figure 9.—Schematic of prism use when target tree is obscured, emphasizing that movement to a clear sight must be along an arc around the target tree that passes through the sampling point.

Gypsy Moth Egg-Mass Counting

Before making a field count of egg masses, it is best to acquaint oneself with the local population, in order to distinguish old egg masses from new or current season's egg masses. No one characteristic can be relied upon for this distinction.

For egg masses within reach, a basic test is the "touch test." New egg masses are generally firm to touch, whereas old ones are soft. Caution must be exercised where new egg masses have few eggs per mass or large quantities of hair per mass. These two factors can often cause new egg masses to feel soft. In cold weather, hands can become numb, thereby reducing the effectiveness of the touch test.

When the eggs are squeezed between the fingernails, if a popping sound is heard, the eggs are new. However, if the new eggs are dehydrated or have been parasitized, this test is less reliable. If the egg mass is within reach, scraping the egg mass apart and watching the eggs fall can give an indication of age. Old eggs are less dense and tend to float to the ground, whereas new eggs tend to descend more rapidly and make a slight sound when hitting leaves or other ground cover.

General appearance can also be an indicator of age. Old egg masses have exit (hatch) holes and have an overall ragged appearance. The older the egg mass, the greater the weathering and raggedness. Care is needed where parasitism of new egg masses has occurred. Both exit holes of old egg masses and points of entry of parasites to the new eggs appear as pinholes in the egg masses. New egg masses may also appear ragged because of predators such as birds or mice.

Color and relative size of the egg masses are less reliable indicators of age. Old egg masses are dull in color and appear bleached out. It is best to see if the color test holds true for those egg masses that can be aged by the previously described methods. If the color test holds true for low, reachable egg masses, it can then be safely utilized to determine age of higher, unreachable egg masses. As the time interval between the deposit of egg masses by the gypsy moth and the egg-mass count increases, the reliability of the color test decreases. Relative size of the egg masses can be used where the previous season's population was stressed. In this case, the new egg masses will be generally smaller than the old egg masses.

By reviewing the above characteristics in the field, particular distinction for age of a given population can be noted and utilized in surveying that population. If the survey is extensive or is to include populations of various ages, be aware of transition zones in these populations. Another indicator which can be used is the forest type. Under stress, the gypsy moth will move into a less favorable or even an undesirable food class. A typical movement of this nature is from oaks to maples and evergreens.

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